WOONASQUATUCKET RIVER BRIDGE
(State Bridge No. 144)
State Route 104 (Farnum Pike), spanning the Woonasquatucket River
Smithfield
Providence County
Rhode Island

HAER No. RI-53

HAER
RI,
4-SMIF,
2-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
Northeast Region
Philadelphia Support Office
U.S. Custom Office
200 Chestnut Street

HISTORIC AMERICAN ENGINEERING RECORD

HAER RI, 4-SMIF, 2-

Woonasquatucket River Bridge (State Bridge No. 144)

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Location: State Route 104 (Farnum Pike), spanning the Woonasquatucket River
Smithfield, Providence County, Rhode Island
UTM: 19.289220.4643515
USGS Quadrangle: Georgiaville, RI 1:24,000

Date of Construction: 1919

Designer:: Clarence Hussey
Engineer, Bridge Department
R.I. State Board of Public Roads
(R.I. Department of Transportation)

Present Owner: State of Rhode Island
Department of Transportation
Providence, Rhode Island

Present use: Vehicular and pedestrian bridge

Significance: The Woonasquatucket River Bridge is one of the few remaining reinforced concrete arch bridges designed by the Bridge Department of the State Board of Public Roads under the direction of nationally prominent bridge engineer, Clarence L. Hussey (1884-1925). This bridge is also significant for its surface finishes, most notably the duochrome finish achieved by the addition of iron oxide to the dry concrete mix. This bridge is the only surviving example of this duochrome finish.

This bridge was determined eligible for listing in the National Register of Historic Places through consensus between the FHWA and the RISHPO on July 6, 1993.

Project Information: The Woonasquatucket River Bridge is structurally deficient due to extensive concrete deterioration. Replacement of the bridge has been determined by FHWA and RISHPO to be an adverse effect. A Memorandum of Agreement was ratified by the FHWA and RISHPO on April 30, 1996. This MOA includes a stipulation requiring HABS/HAER documentation. This report was prepared to satisfy that stipulation.

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HISTORICAL BACKGROUND

The Crossing

Early 19th century maps of the layout of the Farnum Pike in Smithfield indicate bridge crossings of the Woonasquatucket in the general area of Bridge No. 144. RI State Board of Public Roads (SBPR) documents describe a late 19th century truss bridge and its turn of the century replacement, a 40' two-span, timber beam bridge with masonry abutments and a center pile bent. The Bridge Department of the SBPR made substantial repairs to this latter bridge in 1916.[1]

The Woonasquatucket River, the Farnum Pike, and the Stillwater Reservoir

In a course roughly parallel to the Woonasquatucket River, the Farnum Pike (State Route 104) extends from Centredale in North Providence, through Smithfield, to its northern terminus at the intersection with State Route 7 (the Douglas Pike) in North Smithfield. This turnpike, taking its name from two of the original investors, dates to an 1808 State charter. While undergoing changes in ownership and location, the road has been in its present alignment since 1844. In a pattern repeated throughout the State in the early years of the automobile, the Towns of North Providence, Smithfield, and North Smithfield turned the maintenance and improvement of this road over to the State highway system. The SBPR survey of bridges lying on these State roads is discussed below.

The Woonasquatucket River Bridge lies approximately one tenth of a mile downstream from the spillway and dam of the Stillwater Reservoir (1910). This body of water is one of a number of storage reservoirs along the Woonasquatucket and its headwaters. The area known as Stillwater Meadows was surveyed in 1822 by Zachariah Allen as a possible site for a reservoir intended to alleviate the seasonal water shortages affecting factory owners using the power of the Woonasquatucket to drive their textile machinery. This early attempt was unsuccessful. Another attempt to create a reservoir at Stillwater in 1853 was also unsuccessful. Although the Stillwater Reservoir was not actually created until 1910, it is in the location originally surveyed by Zachariah Allen in 1822. Allen led the effort to establish a corporation--the first of its type--in 1823 to impound the waters of Waterman Stream (a tributary of the Woonasquatucket) for the mutual benefit of a group of Rhode Island's early industrialists.[2]

Rhode Island's Concrete Bridges

In 1892 the Rhode Island General Assembly appointed a committee to assess the State's road conditions. In a report delivered to the General Assembly three years later, the Committee "found very little to commend."[3] The eventual result of this survey of some 2420 miles of inadequate roads was the establishment of a State Board of Public Roads (SBPR) in 1902.

The rapid rise of automobile use in the period from 1900 to 1915 spurred many states to establish highway departments. With a pressing need to quickly replace great numbers of deficient or inadequate bridges, these agencies turned to standardized designs that could be easily adapted to the specific characteristics of span, foundation, roadway, and intended use.

In the aftermath of a series of lawsuits concerning injuries and damages occurring on bridges, the courts determined that bridges lying on State roads were part of the State road system. Thus, in

1912 the Rhode Island General Assembly enacted a Bridge Law calling on the SBPR to examine the 156 bridges located on State roads. Upon completion of this assessment, the SBPR was to supervise the construction, replacement, or repair of any bridges "lying in or upon the State roads which had been improved by the State"[4] since the formation of the Board ten years earlier. The investigation would be carried out by a newly-formed Bridge Department under Chief Bridge Engineer Clarence L. Hussey (see **Significance** section).

Hussey was an advocate of concrete bridges. The first reinforced concrete bridge on a Rhode Island public road and constructed under state supervision, the Flat River Bridge in Coventry, had served the state well--and maintenance free--since 1907.[5] In light of this success story, one of the first tasks of the Bridge Department was to standardize a system of reinforced concrete bridge design, a system in which basic designs could be adapted to the varied circumstances of Rhode Island's roads.

The Woonasquatucket River Bridge

Bridge Department engineers surveyed the Woonasquatucket River Bridge in December 1913; it was one of 37 wooden beam bridges of from 5' to 40' span identified in the survey of Rhode Island State roads. This ca. 1900 bridge, replacing a prior truss, consisted of two 19-foot spans with a central pile bent. Overall roadway width was 18.5 feet. The abutments were a combination of regularly coursed ashlar at the face giving way to rough, dry -laid ashlar along the roadway. Bridges of this type had a typical useful life of from ten to fifteen years.

While the timber superstructure of this bridge was probably significantly weathered and unsuitable for automobile traffic, Clarence Hussey, in the January 1920 *Annual Report* of the SBPR, described the placement of footings along the foundation to prevent the collapse of the old walls during the new construction. It was common practice at the time for the Bridge Department to design new concrete structures to fit within the old masonry abutments. This often obviated the necessity of new wingwalls and a temporary bridge, allowing the maintenance of traffic flow during much of the construction of the replacement bridge. This old stone abutment is partly visible at the northwest corner of Bridge No. 144 at the point where it meets the 1919 concrete abutment.[6] Because the new bridge had an increased roadway width of 23 feet, the new concrete abutment could wrap around, and thus retain, a three-foot portion of the old abutment.

Original plans on file at the RI Department of Transportation indicate that the bridge was designed between April and September 1919. Typically, the SBPR replaced older multiple-span bridges of the type described above with single-span concrete arches of from 5 feet to 75 feet in length. Because of the conservation of the old abutments, a new single arch span of 30 feet was designed to replace the older span (with central bent) of 40 feet.

Manuscript records of the SBPR indicate that the job was put out to bid on May 31, 1919. Construction bids ranged from a high bid of $10,950 to a successful low bid of $5,690 submitted by George F. Austin of East Greenwich, RI.[7] Construction was substantially complete by the close of 1919; the bridge was not opened for traffic until early 1920. The Farnum Pike was, at the time, a dirt road. A "new roadway" mentioned in the January 1921 Annual Report of the SBPR probably indicates that the dirt fill required a year to settle; finished roadways over bridges of the period were handled typically as a separate contract.

SIGNIFICANCE

Summary

Built twelve years after the construction of the first State-supervised concrete arch bridge, the Woonasquatucket River Bridge demonstrates the SBPR Bridge Department's early use of standardized designs in a period of rapid expansion of the State road system. Among these standard features were the solid parapet railing with recessed panels, the recessed spandrel panels, and the use of two finish treatments. This bridge is also the only surviving example of the Bridge Department's experimentation with duochrome concrete.

Concrete Bridges

The use of concrete as a construction material dates to the Hellenistic period when Greek engineers used it in the building of aqueducts. Concrete's first wide use is, however, associated with the Romans, who combined locally available volcanic sands with lime and aggregate as early as 200 BC. This combination provided a durable material, often used in combination with masonry or brickwork, that survives to the present in surprisingly good condition. Although there is evidence of the use of bronze rods for reinforcement,[8] Romans used concrete primarily as a masonry substitute, a material strong in compression but weak in tension.

Concrete fell into disuse during the Middle Ages and was not reintroduced until the mid 18th century. In 1824 Joseph Aspdin produced "Portland" cement by the careful measurement and mixing of limestone and clay. The resulting stone-like material resembled the Portland building stone commonly used in England, hence the name. While Portland Cement, mixed with aggregate to make concrete, was superior to its ancient counterpart, it was not until the mid-19th century reintroduction of metal reinforcement that concrete came to be used as a material with strength in tension as well as compression.

By 1870 French engineers had employed plain concrete in the construction of arches for the Grand Maitre Aqueduct, part of the Parisian water supply.[9] On this side of the Atlantic, Ernest Ransome built the first reinforced concrete arch bridge in San Francisco's Golden Gate Park in 1889. Although this bridge represented a significant advance in bridge construction, its conservative design and surface treatment evoked the masonry types that preceded it. By the turn of the century, a new generation of bridge designers would begin to grasp the structural potential of reinforced concrete and begin to design to those possibilities.

Clarence L. Hussey

Among this new generation of bridge designers was Clarence L. Hussey. Relocating to Providence after his graduation from Massachusetts Institute of Technology in 1908, Hussey worked in various capacities in the engineering field before joining the R.I. State Board of Public Roads in 1912. The Board had recently established a Bridge Department to oversee the design, construction, and maintenance of the State's highway bridges. Hussey was hired as Chief Bridge Engineer. In this capacity, he supervised the general bridge survey of 1912 and 1913 and provided engineering supervision for the design and construction of the standardized bridge designs required for the rapidly growing State transportation system. Hussey had a profound influence on bridge design and construction throughout the state between 1912 and 1925.[10]

An expert in the relatively new field of reinforced concrete construction and a nationally-recognized bridge engineer, Hussey formulated new, stronger concrete mixes and applied this knowledge to innovative and cost-saving bridge designs. One of the most notable of these innovations was the modified arch bridge, a design that saved as much as 50% of the concrete normally required for a span of comparable size. The modified arch had inclined, rather than vertical, spandrel walls and sidewalks and railings that were carried on brackets anchored to the arch ring. In the words of an American Society of Civil Engineers remembrance of Hussey published after his death in 1925, "His ideas, although marked by striking originality, had the saving virtue of reasonableness."[11] Hussey designed the Washington Bridge between Providence and East Providence, the original span of which still carries eastbound traffic over the Seekonk River. He also designed the only concrete through-arch bridge in Rhode Island. Completed in the last year of his life, it spans Wickford Cove and is appropriately named the Clarence L. Hussey Memorial Bridge.

DESCRIPTION

The Woonasquatucket River Bridge is a single span, reinforced concrete, solid spandrel arch bridge spanning the Woonasquatucket River on the Farnum Pike (State Route 104). It is approximately 100 yards below the spillway and gatehouse of the Stilllwater Reservoir in the Town of Smithfield, RI.

The bridge has an overall length of 44 feet and an overall width of 25 feet. The abutments are formed in the shape of a squared *U*, four feet in thickness at the face of the old masonry abutments and enclosing them a distance of three feet, thus giving the abutments an overall depth along the roadway of seven feet. These abutments are approximately 15 feet high to the underside of the endpost coping. There are no sidewalks. The road surface is 22' 8" wide (parapet to parapet), rising approximately 12" at the crown, and surfaced with bituminous macadam.

The single arch is approximately 30" thick at the skewback, tapering to a thickness of 12" at the crown. Viewed in elevation, the arch intrados is marked by a recess and radius formed in the concrete. The vertical surface of the arch drum is raised slightly over the solid spandrel panel. This accenting of the arch drum is in keeping with the general design of SBPR bridges since the formation of the Bridge Department in 1913.

The earliest bridges of the SBPR had an urn-shaped open balustrade railing. The experience of the Barrington and Warren Bridges (built during 1912-1914) encouraged the Bridge Department to consider more durable railing designs. It was discovered soon after the construction of these two bridges that an errant automobile could easily ride up on the curb and destroy a length of railing. To address this, the Bridge Department adopted two types of railings: a solid parapet with recessed panels and an open balustrade with chamfered square balusters.

The parapet wall is 18" thick with a chamfered 4" high cap running its entire length. An added 1" cap (14" wide) is found on the endpost caps. From the roadway the parapet rises 36". While the SBPR found the ornamentation of an open balustrade unnecessary on small rural bridges, the solid parapet wall was marked by a repeating pattern of recessed, 21" high, "tool-dressed" panels to break the visual monotony of plain concrete. These six panels were 1" deep and bevelled at a 45 degree angle. The five panels are not of a uniform length: the center panel is 66" long, the second and fourth panels are 63", and the outermost panels are 60". This visual effect created the illusion of equal-sized panels when viewed from the shoreline. While demonstrating a noteworthy attention to detail, it is arguable how effective--or necessary--such a treatment was on a 31' section of railing. The parapet terminates in two 6' 6" endposts. The base of the parapet at the outside elevation is marked by a chamfered 8" (overall) coping that protrudes 3" from the face. Though damaged and significantly weathered, the parapet and spandrel walls still show two different surface treatments,--"tool-dressed" or "bush-hammered" recesses and smooth, or "polished" raised surfaces.

The four endposts of the bridge originally carried identification markers inscribed: "State Board of Public Roads 1919" and "Woonasquatucket River Bridge 144." Because of the extensive deterioration of the northeast endpost, that marker is missing. The three remaining markers are of the blue and white ceramic type, recessed into the concrete face of the endpost. This type of marker, replacing the inset brass numerals used on the first SBPR bridges, was employed from

1918 to the 1940s.

Present Appearance: From the roadway, the appearance of the bridge is essentially unchanged from its 1919 construction (with the exception of the deteriorated northeast endpost). The elevations exhibit extensive spalling concrete, notably at the arch drum. A modern steel guardrail extends from--but is not attached to--the four endposts of the bridge.

Aesthetic treatment: A central tenet of modernism, as embraced by designers early in the 20th century, was the belief that the form of a structure should reveal its function clearly and simply. In this spirit, the Bridge Department wrote in 1916:

> The designs prepared for State bridges are practically devoid of ornament and this condition makes the proportion and balance of the masses of a plain structure more important; and in consequence the lines and proportions of the new bridges have been carefully studied.[12]

This attention to line and proportion--even in the case of a remote rural bridge--is evident in the surface treatments of the Woonasquatucket River Bridge. Though lacking any surface ornamentation, the bridge displays two colors and two surface textures of concrete. The raised surfaces of the bridge were rubbed or "polished" to a smooth plain concrete finish; the recessed spandrel and railing panels were "bush-hammered" and tinted with iron oxide to provide a visual contrast. Although still evident, these distinctions in surface treatment and color are now muted due to years of exposure to weather.

The SBPR began its experimentation with concrete coloration ca. 1915. The first actual use of coloration occurred early in 1919 with the construction of the Fairbanks Bridge No. 177 in Coventry, RI. This bridge, replaced in 1927, exhibited the same coloration technique as the Woonasquatucket River Bridge.

Technical literature of the period indicates that there were three methods commonly used in the coloration of concrete: the substitution of a naturally-colored aggregate (such as pink marble) for standard gravel, the use of organic colors, or the use of mineral colors. The effects of organic coloration were short-lived due to leaching and exposure to sunlight; and improper mixing could seriously compromise the strength of the mix. The addition of colored aggregates represented an added expense as well as added operations, as the coloration was often applied in the form of a facing coat.[13] The Bridge Department settled on the use of mineral additives, specifically, iron oxide. Because no color photos from the bridge's early years are known to exist, we cannot determine the extent to which the iron oxide mix has faded since 1919. The current pink hue is, however, similar to the pink wash used by the draftsman to indicate color in the original inked construction drawings. A 1921 article in the *Proceedings of the American Concrete Institute* described the use of iron oxide "from which the pinks to reds are produced." [14] Excerpts from this article are found in the **Supplemental Materials** section of this report.

There have been no major alterations or repairs on the Woonasquatucket River Bridge since the time of its construction.

NOTES

1. *Eighteenth Annual Report of the R.I. State Board of Public Roads* (January 1920): 82. A few hundred feet downstream are the remains of a concrete railroad bridge abutment; this bridge carried the now-defunct Pascoag Branch of the New York New Haven & Hartford Railroad over the Woonasquatucket River.

2. For a detailed description of the efforts of Zachariah Allen to incorporate the Wonasquatucket River Company and his later efforts to create a reservoir at Stillwater, see Richard E. Greenwood, *"Scientific Engineering and Useful Improvements": The Manufacturing Career of Zachariah Allen, 1822-1872.* Ph. D. dissertation, Brown University, 1996.

3. *Report on the Roads and Public Highways of Rhode Island.* Providence: E.L. Freeman, 1895.

4. *Eleventh Annual Report of the R.I. State Board of Public Roads* (January 1913): 29.

5. This bridge, a 75' reinforced concrete arch (No. 71), was removed in 1954 because of its narrow 16' wide roadway and replaced with the current bridge.

6. *Eighteenth Annual Report of the R.I. State Board of Public Roads* (January 1920): 82.

7. *Records of the R.I. State Board of Public Roads*, Volume V, p. 320.

8. Harrison Howe, *The New Stone Age* (New York: The Century Co., 1921), pp. 85-86.

9. This structure of some 135 miles was intended to be built of masonry and cast iron. The chief engineer of the project, a M. Belgrand, chose to use the *beton-agglomore* of Coignet for a 37-mile section of the aqueduct notable for its difficult topography. For a thorough discussion of the project see "The Aqueduct of La Vanne." *The Manufacturer and Builder* 2 (May 1870): 143-5,. While the use of reinforcement is not discussed in this article, it is briefly mentioned in Harrison Howe, *The New Stone Age*, New York: The Century Co., 1921, p. 86.

10. At the time of Hussey's hire, Walter Denman, a representative of Daniel Luten's National Bridge Company made a presentation to the SBPR on the benefits of the "Luten System of Concrete Bridges." Luten's Company had, by this time, built or supervised construction of more than a thousand reinforced concrete bridges throughout the country. The State adopted this system shortly after, retaining Denman and Luten as design engineers. It is doubtful that this relationship was based on a lack of confidence in Hussey on the part of the SBPR; Luten's holding of basic patents could have exposed the State to possible infringement lawsuits. By late in the decade, some of Luten's proprietary claims to basic concrete bridge elements (particularly arch design) were challenged successfully in court. Hussey, who adapted the general Luten designs for the specifics of Rhode Island crossings, was clearly in charge of SBPR bridge design. While Denman's name appears on a few early bridge drawings (e.g., Hopkins' Mills Bridge, Foster RI), the involvement of Luten and Denman disappears shortly thereafter. Still, Daniel Luten's insistence on clean, spare designs in harmony with their natural environment is very much corroborated in the work of Clarence Hussey.

11. George Henderson, "Memoir of Clarence Loring Hussey," *Transactions of the American Society of Civil Engineers* (1926) p. 1632-33.

12. *Fourteenth Annual Report of the State Board of Public Roads* (January 1916): 50.

13. K.A. Hatt. "More Facts About Color in Concrete." *Concrete* 28: (June 1926): 44.

14. See John W. Lowell. "Coloring Concrete." *Proceedings of the American Concrete Institute* 17 (1921): 122.

SOURCES OF INFORMATION/BIBLIOGRAPHY

Engineering Drawings:

Two original construction drawings (144,001 and 144,002) are on file at the Rhode Island Department of Transportation, Plan Room, 2 Capital Hill, Providence, Rhode Island.

Historic Views:

Fourteen black and white photographs (approximately 3.25" x 5.5" format) documenting the previous bridge, the current bridge (as-built), road oil damage (1934), and spalling (1966) of the Woonasquatucket River Bridge are on file at the R.I. Department of Transportation. The corresponding negatives are on file at the Rhode Island State Archives, 337 Westminster Street, Providence, R.I.

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Two folders of contract-related documents for both phases of construction. On file at Rhode Island State Archives (RIDOT collection)

Government Documents:

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Clouette, Bruce and Roth, Matthew. *Rhode Island Historic Bridge Inventory.* Providence: RI Department of Transportation, 1988

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Supplemental Material

The following are excerpts from an article by John W. Lowell of the Universal Portland Cement Company that appeared in the Proceedings of the American Concrete Institute *XVII (1921).*

Coloring Concrete

Text and experience have fairly well circumscribed the use of mineral coloring matter in concrete. One cannot say that any mineral coloring used in concrete will give a permanent color for weathering can spoil any color. Weather action, coupled with the effects of the rays of the sun and the action of the alkalies resulting from the hydration of the cement , gives complex reactions which make necessary the most careful selection of colors with regard to permanency.

Practical results obtained by users of colors in solving their own problems, combined with the experiments and experience of the manufacturers in meeting the need for such materials, have limited, with a few exceptions, the raw materials and colors now on the market to those which have been found to work most satisfactorily and to give the most durable colors.

These raw materials are:

Red iron oxide from which the pinks to reds are produced.
Brown iron oxide which gives the browns.
Iron hydroxide, from which yellows to buffs are obtained
Manganese dioxide, lamp black or *carbon black,* from which are produced blue slate and blue-gray colors approaching black.

....

These materials come in the form of a powder or paste. The powdered form is the most satisfactory.

Only a pure grade of these mineral colorings should be used.

Quality of mineral coloring and the color of the cement and aggregate will affect the tones obtained. With the pure mineral colorings named the formulas in Table I may be used in working out different tones by varying the quantity of coloring material.

TABLE I (excerpt)

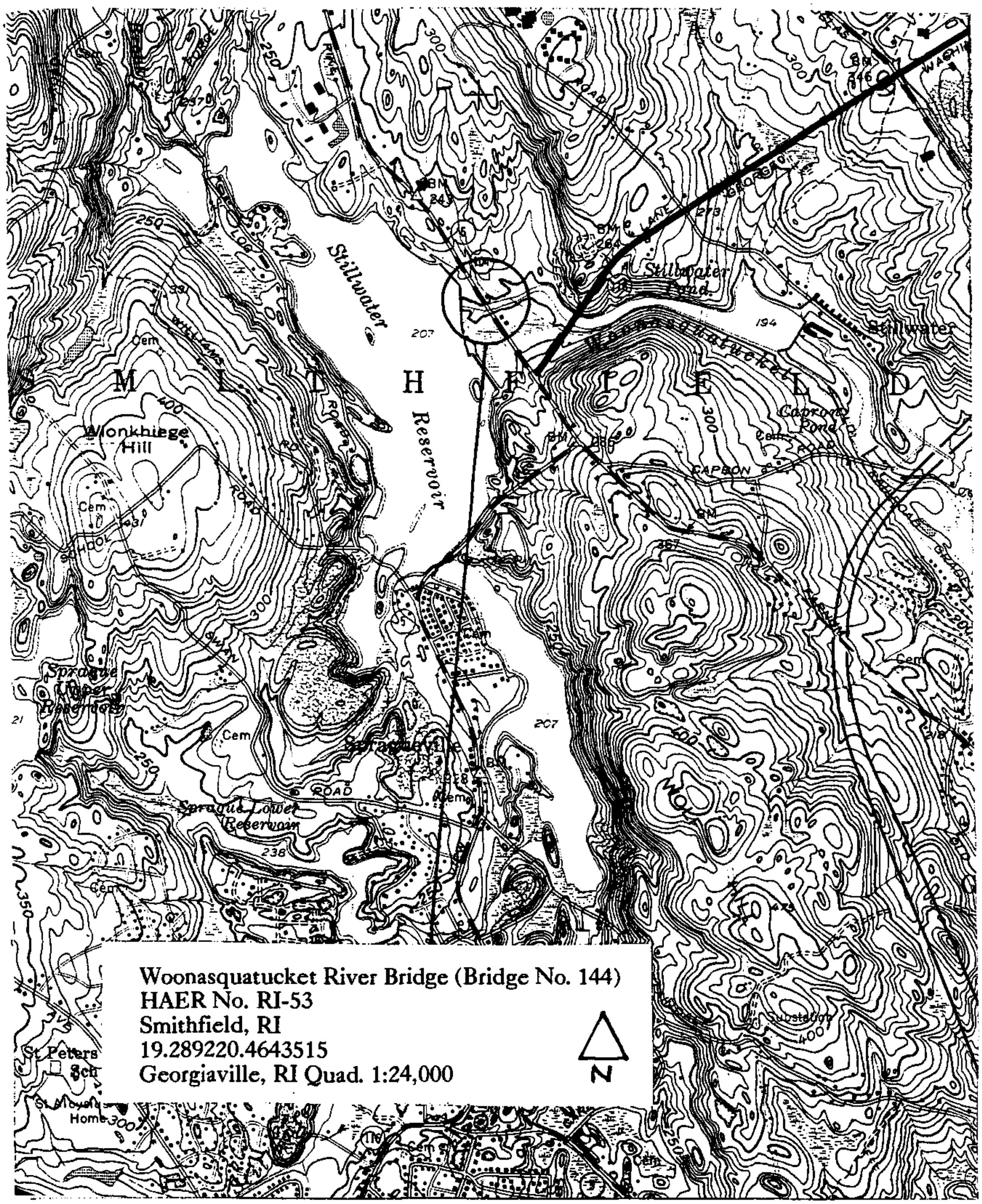
Color desired	Quantity of Mineral Coloring for 100 lbs. of cement
Pink	1 lb. Red Oxide of Iron
Terra-Cotta	2 lbs. Red Oxide of Iron
Light Brick Red	4 lbs. Red Oxide of Iron
Red	6 lbs. Red Oxide of Iron

Manufacturers prescribe the quantities of their mineral colorings to obtain required colors.

Careful weighing and mixing of the mineral coloring with the other materials is absolutely necessary. In hand mixing a predetermined weight of the powdered coloring matter should be added to each batch of dry fine aggregate and these materials mixed together. The cement is then added and the whole thoroughly mixed by shoveling from one pile to another through a 1/4-inch mesh wire screen until the batch is of uniform color. Water should then be added to bring the mortar to the proper consistency.

Better and more uniform results may be obtained by using a machine for dry mixing the cement and coloring material. Such machines vary from small sifters to specially designed grinders which not only mix the two materials, but also grind the particles together. This will give the maximum benefit of the color and add to its durability.

The use of mineral colorings for outside work is limited by the choice of colors and by the strength requirement of the concrete, limiting very closely the amount of admixture that may be safely added. Not over ten per cent mineral coloring by weight of the cement should be used.


Stillwater
Reservoir
Stillwater Pond
Stillwater
Woonasquatucket
S M I T H F I E L D
Monkhiege Hill
Capron Pond
Sprague Upper Reservoir
Spragueville
Sprague Lower Reservoir
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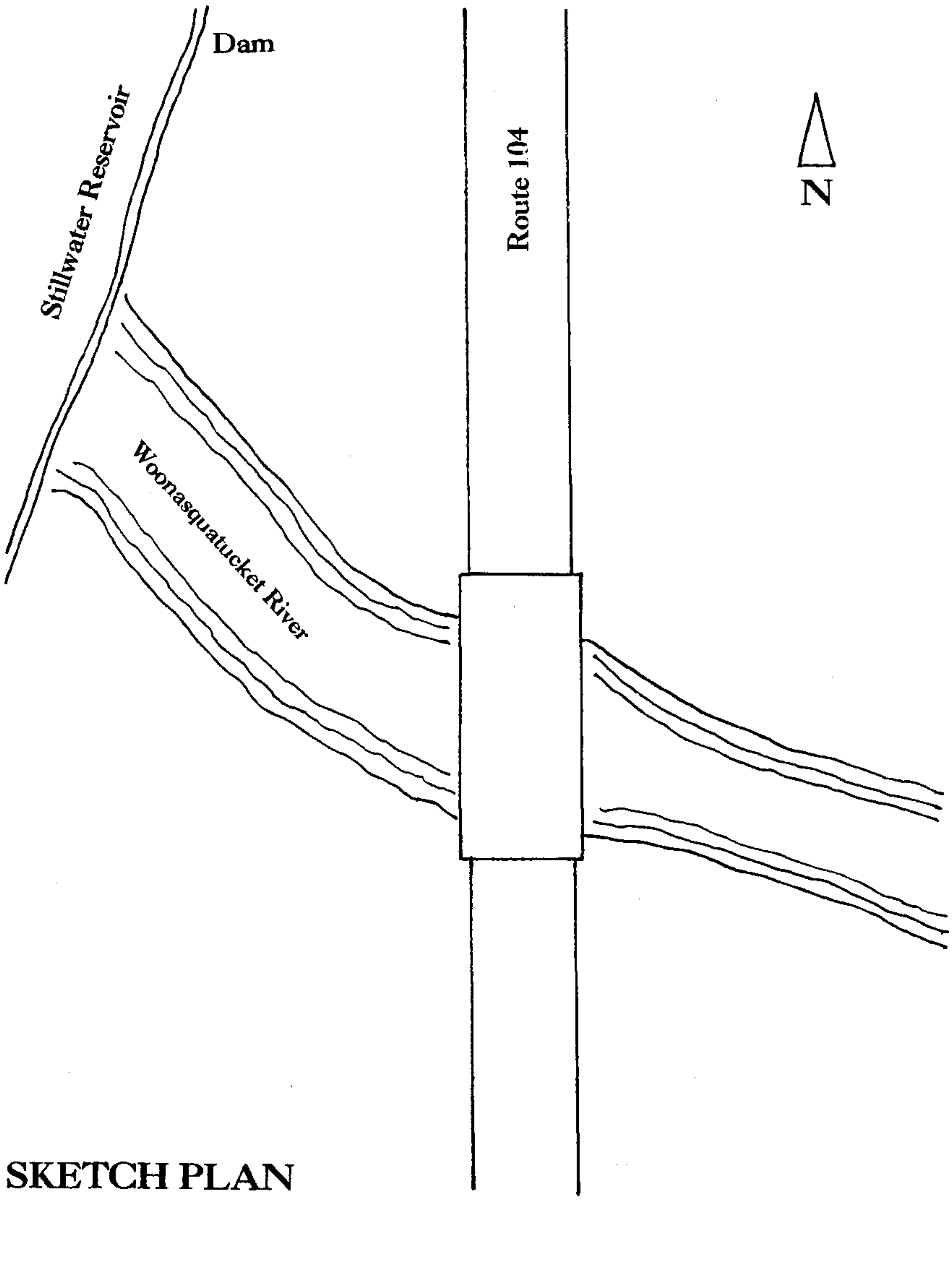
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SKETCH PLAN